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POST-PRODUCTION SYSTEMS RESEARCH IN DEVELOPING COUNTRIES

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The 1960s saw a significant increase in overall per capita food production throughout the world, particularly in Asia, Latin America and the Near East. Based upon the best statistics available, food production in the less developed countries maintained only a slight lead over population growth. During the 1970s, in both developing and developed economies, food increase per capita tended to decline. Only Asian countries apparently produced more per capita in the 1970s than in the 1960s. Among the poorest of the least developed countries, particularly those in Africa, the rate of population increase during the past decade significantly outstripped increase in food production.

In 1975, the difference between demand and supply in cereal grain equivalents in the developing countries was about 40 million tonnes. Based upon detailed recent forecasts, by 1990 the shortfall will lie somewhere between 100 and 150 million tonnes, that is between 2.5 and 3.5 times the deficiency of 1975.

Clearly then, very much greater efforts must be made throughout all the world to increase per capita food availability, a goal that can be reached by three simultaneous broad strategies:

1. The attainment of higher levels of productivity per unit of land;
2. The expansion of the area of land under cultivation; and
3. The achievement of a much greater efficiency in food conservation and distribution.

NOTE: The views expressed in this paper are those of the author and do not necessarily represent those of the International Development Research Centre.

In most relevant publications, the first two strategies receive greatest emphases; much greater importance seems to attach to increasing production than to achieving more efficient post-production systems of conservation and distribution. The success of the international agricultural research centres (IARCs) in increasing cereal grain production through higher yielding cultivars is well documented. During the 10 years from the mid-1960s, when the higher yielding plant types of rice and wheat were introduced, average rice yields in developing countries increased by 17% and total production by 27%; wheat yields increased by 24% and annual production by 50%. Now that comparable international research programs are underway, it appears that other food crops, which when compared with wheat, rice and maize have been relatively neglected, may be capable of even more spectacular yields when subjected to careful genetic selection combined with improved agronomic practices. It is clearly evident however that without an investment in post-production research and development comparable to that which is being made in production technologies, the benefits of higher yielding plants and more efficient agronomic systems will never bring benefit to the majority of the rural and urban poor of the less developed regions.

It is estimated that the world produces sufficient grain to provide at least 3,000 calories per day for every man, woman and child alive. This takes no account of the additional calories and nutrients that are available in the form of fruits and vegetables, fish and other animal products husbanded and harvested. Since it takes little more than 2700 calories a day to sustain a moderately active adult, millions suffer malnutrition because existing systems are inadequate to make a fair and uniform distribution of the available food supplies from the regions and seasons of abundance to those of scarcity.

The inadequacy of post-harvest distribution systems is not confined to the transfer of the surplus grain crops of Australia, Canada and the United States, though such transfers to developing countries on both economic and concessional terms will be required long into the foreseeable future. Inadequate post-production systems exist among many regions, countries, zones within countries, communities, and even within families.

Wide seasonal variations are apparent in many developing nations, for example in the Sahelian zone of Africa the period from December to mid-March, which immediately follows the harvest, is a time of relative abundance. But between April and July, food supplies tend to dwindle until August and September when serious dietary deficiencies are to be found among those rural people who do not maintain an adequate store or who lack the disposable income to buy cereals and legumes from grain traders. A recent study carried out in Senegal indicated that where food energy intake is adequate during December, dietary energy levels fall to almost 30% below what is recommended during August and September, the period immediately before the harvest.

The relatively unsatisfactory state of nutrient distribution among the developing countries may be attributed to economic, social, logistic and technological causes, all of which tend to vary in kind and/or degree among different communities. There are two contributing causes that are often overlooked. The first is the need to consider each post-production system in its entirety; the second results from an unwarranted optimism in the transferability of technology.

Scientific principles are universally applicable; many technologies are not. Technologies based upon biological principles whether they relate to the cultivation of edible plants or to the transformation, preservation and distribution of plant or animal products are greatly influenced by the physical, social and economic environments that surround and condition them.

Consequently, it is often impossible to transfer post-production technologies, including many food processing and transformation systems from developed countries with temperate climates and access to advanced technologies, into the less developed countries of the arid, semi-arid and humid tropics.

Post-production systems need to be studied comprehensively and in their entirety and their component technologies must be developed where they are to be used and in close cooperation with those who are to use and benefit from them. Post-production systems research must begin with a thorough examination and understanding of the systems that already exist, however primitive they may appear to be. Only by comprehending what already exists and by analyzing all of the relevant technical, economic and social factors that pertain can one hope to devise and implement improved post-production systems together with their appropriate component technologies. It cannot be too heavily emphasized that inadequate attention has been addressed to the fate of food crops, and other food sources in developing countries from the time they are harvested until the time they reach the consumer's meal table. This sequence of interdependent events from harvest to consumer constitutes the post-production system, a system that varies greatly in its degree of complexity, dependent upon the prevailing social, economic and physical environment.

It is often stated that post-production, or post-harvest losses may be as high as 30% of the harvest. If this is so, a 50% increase in production is necessary simply to replace what is lost between the harvest and the consumer. It is not improbable that the concept of post-harvest loss contributes to its cause. It appears that many supporters of international agricultural research appear attracted more by research that will increase production than by research dedicated to the reduction of post-production losses. It seems that even the

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most imaginative minds have difficulty in accepting that two negatives make a positive: that by reducing losses, one effectively increases productivity. Perhaps therefore it would be more appealing if the negative concept of reducing post-harvest losses were replaced by the positive objective of creating more efficient post-production systems.

The scope of different post-production systems varies greatly in complexity. Among the simplest subsistence systems, the crop is grown, harvested, threshed, stored, processed, and eaten by a single rural family. Among the highly developed agricultural economies, many more people and much greater investments of money and energy are consumed in the post-production systems than in the production of the original food crops.

The Canadian agricultural system absorbs about 16% of our total national energy consumption. At present, about 80% of all foods consumed by Canadians requires some post-harvest energy input. Clearly the biggest users in the Canadian food chain are the food processing industries; the following being the approximate proportions of energy used by the various segments of the agricultural production and utilization system:

AGRICULTURAL PRODUCTION	18%
PROCESSING AND PACKAGING	32%
TRANSPORTATION & DISTRIBUTION	20%
HOME PREPARATION	30%

Post-production research is essentially systems research and yet the components call upon many specialized disciplines from the physical, biological and social sciences, together with a comprehension of all of the social, economic and physical environments by which the post-production system is conditioned and constrained. One could cite many instances in which post-harvest losses have increased and inefficiencies in post-harvest systems have been aggravated by projects that sought to modify a single component of the post-production system out of context to the whole

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system and to the environment in which the system exists. It cannot be too heavily emphasized that a grain dryer or storage facility that may be suitable for wheat in Manitoba or Minnesota can be disastrous when applied to a wet paddy crop in Malaysia.

Because of the non-transferability of many biological technologies, already referred to, it is my firm belief that all post-harvest systems and the technologies of which they are composed must be developed wherever they are to be applied and in close cooperation with the rural people who will use and benefit from them. It is a *sine qua non* that the first essential in the development and elaboration of any technological component of a post-production system is a comprehensive understanding of the system as a whole and a clear identification of those persons and communities by whom the system will be used and those whom it seeks to benefit.

One of the most sure formulas for disaster is to start the post-production research process in a research laboratory particularly one in a developed country with the ultimate objective of translocating the technology and persuading poor people of developing countries to adopt and use the technology. Post-harvest technologies developed in scientifically and economically advanced countries tend to be too complex, too highly engineered and too difficult if not impossible to maintain among the rural communities of the third world. However, though labour intensive systems and technologies are generally more desirable among the rural communities of the developing world, some degree of appropriate mechanization is necessary in many developing countries. Studies carried out in a project financed by IDRC indicated that an African woman's typical working day includes 7 to 10 hours devoted to finding and carrying water, collecting wood, grinding grains and preparing meals. In addition, the time spent working in the field, though it varies among seasons, calls for many hours

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of hard physical labour. For example, a study in Uganda indicated that between 50 and 70 man-days per hectare are required to harvest the millet which is the staple cereal. Consequently, appropriate mechanization of the post-production system can benefit the people of the poorest developing countries. Many African women interviewed expressed a need for a village-scale cereal grain milling facility in order to free them of the drudgery of hand-pounding and liberate them for more rewarding activities such as raising small animals and kitchen gardens.

In Egypt, a parastatal organization has developed a mechanized system for small farmers in which one single light-weight 10 hp diesel engine provides power to several specially designed threshers, drills, planters, sprayers, and pumps, and also to a general utility transport vehicle. The system can be owned cooperatively or provided on a rental basis by the State and is specially suited to smallholder farmers who work on less than 1.5 hectares of land. Elsewhere in Africa, hand wheel or bicycle operated threshers are finding acceptance.

Though the people of most developing countries may derive their essential nutrients from a wide range of food sources, the majority rely upon cereal grains, root crops and food legumes for most of their energy and protein. There exists a substantial volume of literature on the breeding and agronomy of cereals and legumes relative to grain yield and chemical composition. In contrast, and with the exception of wheat and rice, relatively little is to be found on what determinable factors influence post-harvest stability, nutrient availability, and such useful properties as milling quality and cooking characteristics. Similarly very little serious attention has been given by scientists and technologists to improving the means by which to preserve and process root crops other than potatoes.

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The next stage in the post-production sequence calls for more research and technological development in the drying and storage of harvested food crops. Most fresh plants and animal tissue, other than fully ripened seeds, contain from 75 to 95% moisture. To minimize post-harvest deterioration, a safe moisture content must be attained as soon as possible after harvest. Moisture content affects virtually all post-harvest operations. No matter what method of harvesting is used, drying of the crop to a moisture content no higher than 12% is desirable before threshing and storage. During sun drying, it is the solar radiation that evaporates the moisture and the wind that carries the moisture away. Consequently in stacked grain,sufficient air space must be provided to take advantage of prevailing winds. In many countries one observes most crops being dried simply by spreading them on the ground and exposing them to the sun and wind. In addition to inadequate control, this kind of traditional system has the disadvantage of exposing the grains to attack by birds, rodents, insects and other undesirable contaminators.

As an example of how to apply scientific principles to a simple technology, a scientist in West Africa determined the zenith angle of the sun and the prevailing direction of the wind for all times of the year over an extensive farming region where cereals and legumes are the principal crops grown. From the data collected it was possible to construct simple grain drying racks that take maximum advantage of the sun and wind in the drying process. In effect, what the scientist created was a natural cross-flow grain dryer, dependent only upon the natural elements as energy sources.

The threshing of grain is a source of very great loss, particularly in traditional systems in which the grain is threshed by hand, long after harvest without adequate prior drying. Also, threshing offers a number of examples of inappropriate transfers of technology. For example, a thresher developed for smallholder mechanized threshing of rice in Asia had to be significantly modified when used for threshing wheat, barley, sorghum or millet in the Near East.

Probably more has been written about storage than any other component of post-production systems. Many of the advocates of the benefits of hermetic storage do not appear to realize that storage in totally sealed containers was known in the Middle East more than 5,000 years ago. Though the length of time the harvested food crop needs to be stored may vary from a few days to many months, there is an evident need, particularly in the poorest rural communities for storage systems that will adequately protect cereal and legume crops not only from one harvest to the next but between crop years to ensure an adequate surplus carry-over in case of a later poor harvest such as occurs frequently and often unpredictably in the semi-arid tropics and other regions where rainfall is low and uncertain and where alternative irrigation is unavailable.

A recent study carried out in the Sahelian zone of Africa revealed that relatively few farm families and rural communities have adequate storage even to carry sufficient grain for human need from one harvest to the next. The resultant malnutrition is aggravated by the fact that greatest work loads are demanded at the time of greatest shortage, that is, immediately before the harvest.

The tropical environment, together with the physical limitations of some of the traditional structures used for crop storage account for many of the high losses that occur post-harvest. Nevertheless, a perceptive and critical assessment of comparative advantages and limitations of traditional structures and methods often reveal a potential for improvement at a much more reasonable cost than is demanded by systems of storage fabricated and imported from elsewhere.

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In research supported by IDRC in West Africa, it has been shown that provided the grain is first adequately sun dried, then tightly packed into the traditional woven crib, the storage life is equivalent to that of grain stored in much more expensive bins designed and imported from developed countries. Satisfactory grain storage depends upon the control of three variables: moisture, temperature and oxygen. These can be largely controlled by efficient grain drying, design and construction of the storage bins, and the observance of certain precautions. In general, the larger the bin the more efficient the storage becomes since the bulk of the grain is insulated to a greater extent from changes in outside conditions. It is essential the grain be cool when the bin is filled, therefore grain is best filled into the bin early in the morning, before the sun is up.

Generally, a bin should be about equal in height and width to reduce moisture and temperature gradients to a minimum. If the width is much greater than the height, high temperature variations will cause condensation, moisture gradients, with consequent grain losses caused by mold growth at the points of highest moisture content. Solid wall bins of woven structure reinforced by mud provide better insulation from outside air temperature and maintain lower temperature and moisture gradients within the grain. Installation of a large roof with an overhang over the bin or crib greatly reduces the fluctuations in grain temperature with changes in ambient day and night temperatures. Metal storage bins are generally unsuitable for the tropics because of their rapid absorption and conductance of solar heat. Several instances have been observed in which metal bins filled with grain and exposed to direct sun have assumed the nature of pressure cookers, the moisture being driven from the periphery to the center where the moisture content reached a sufficiently high level to cause steam cooking of the grain.

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A more comprehensive review than is possible in this presentation, of the various alternative technologies and factors that influence primary and secondary processing of the subsistence crops of the developing countries, was recently presented and will be published by the Kuwait Institute of Scientific Research.

For many technical, biological, social and economic reasons, grain milling technologies designed for temperate developed countries are usually unsuitable for use by rural communities of Africa, Asia the Near East and Latin America. The continuous processes of dehulling, grinding, particle size classification, blending and packaging developed in Europe, North America and Japan for wheat, maize and rice, depend upon a raw material grain supply that is uniform in moisture content, grain size and structure. In contrast, many rural communities are required to process grains varying widely in moisture content, composition, size and condition. Furthermore, in the semi-arid tropics of Africa, the equipment in a single grain mill is required to process several different cereal grains and legumes. This requirement is not unattainable in the corregated and smooth roll break and reduction systems used for wheat in the developed countries of the world, in which the grains are first carefully graded according to seed size to permit uniform milling and separation of the various milled fractions. Rural mills must be capable of dehulling seeds widely different in nature, genetic and agronomic background, and of providing milled products that vary significantly in particle size. Because of its larger seed, sorghum is generally more easily debranned than is pearl millet: dried legumes present particular problems because of widely different shape and size, and the variation in strength of the adhesion between seed coats and cotyledons.

A successful attempt to establish a rural multi-purpose grain and legume milling system is to be found in Maiduguri in the Northeast State of Nigeria. This project, which began in 1972,

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provides an example of the manner in which a virtically integrated systems research approach will lead to a rational post-harvest system composed of appropriate locally developed and adapted component technologies. Maiduguri, a city of some 150,000 people, lies in an area where the main crops are sorghum, pearl millet, maize and cowpeas with smaller quantities of wheat grown on irrigated land.

Though the heart of the Maiduguri system consists of a relatively simple yet novel milling unit, the project encompasses a wide spectrum of post-harvest activities including threshing, drying, storage, primary and secondary processing, product evaluation, packaging, marketing, consumer acceptance and utilization. The original purpose was to reduce post-harvest grain losses that resulted from relatively inefficient methods of handling, storage and processing and thereby to increase the monetary return to farmers by offering a more economic and attractive system for grain purchase, storage, transportation, processing and sale. The processing technology was to provide machinery capable of processing the different locally produced cereal grain and legumes into acceptable milled flour and secondarily processed traditional and novel food products.

The project began with an extensive socioeconomic study of the existing post-production food grain systems throughout the area around Maiduguri. Economic surveys showed that most of the grains produced were retained on farms and that only about 15% of the grain harvested entered market channels. The grain that was mechanically processed was ground on a custom basis into whole grain flours in small plate mills driven by diesel engines.

A consumer demand and attitude survey was carried out in 1100 households in Maiduguri by women students and members of the Home Economics Department of the State Government in order to determine the type and volume of cereal and legume

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products in greatest demand, to indicate the nature and volume of flour the pilot mill should produce, and to develop a consumer information program to encourage improved household utilization of the processed cereals and legumes to be made available. The consumer preference study showed a growing demand both for commercially packaged flour from which local women could prepare traditional foods, together with a significant shift towards secondarily processed cereal foods thus revealing an opportunity for developing more nutritious foods from combinations of cereal and legume flour. The greater flexibility offered by the proposed mill would, it was believed, make possible a wider choice of acceptable and economic convenience foods, together with the supplementation of traditional cereal foods with legume proteins, and the substitution of sorghum, millet and cowpea flours for imported wheat in both traditional foods and baked bread.

The mill made possible the development of a range of new and appetizing foods composed entirely of sorghum, millet, maize and cowpea flours, that are now sold to local markets for immediate and household consumption. The pilot mill and its ancillary facilities concentrate upon four main processing components: (1) the decortication and milling of sorghum, millet, cowpeas and maize; (2) the production of bread and snack foods based upon the grains milled; and (3) the development of modified traditional and relatively new food products which are now forming the basis of a communally owned commercial food processing industry.

The first step after cleaning and simply grading the grain involves decortication by abrasion followed by separation of the seed coat through simple aspiration and sieving. This is followed by the grinding of the endosperm and residual germ in a hammermill.

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The decorticator consists of a series of carborundum stones mounted on a horizontal shaft spaced at 1 1/2 to 3 cm intervals. The rotor so formed is mounted in a rubber lined metal case with a clearance of about 2 cm at the sides and around the bottom of the rotor. A screened air inlet along one side of the top and an air outlet at the opposite side attached to an aspiration system automatically removes the fine bran particles as they are abraided from the cereal and legume grains. After dehulling, the grains are transferred to a hammermill followed by a flour sifter in which the ground endosperm is separated into fine flour, middlings and semolina.

A more recent development involves the replacement of the carborundum stones with lighter resinoid discs. Carborundum stones must be formed into thick sections to be rotated safely at speeds in excess of 1000 rpm. These thick heavy stones have two disadvantages; first the relatively high power demand required to rotate them and second the reduction in the abraiding surface area available for any given weight of grain. Resinoid discs, made by bonding aluminum oxide into a plastic matrix, may be formed into very thin, light, strong sections that can safely be rotated at speeds of more than 6400 rpm. The use of resinoid discs in the dehuller provides more than twice the abrasive surface at only one quarter the weight of the carborundum stones with a consequent significantly lower power consumption per kg of grain dehulled.

Because the Maiduguri mill is intended to satisfy consumer needs and demands, a test kitchen has been established to serve both as a quality control laboratory and a development unit for the elaboration of nutritionally improved traditional and novel foods. The mill achieves a recovery rate of between 70 and 80% by weight of the original grain compared with less than 65% useable grain from manual decortication. Consequently, the mill provides

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significantly larger quantities of edible milled grain in addition to salvaging and using the by-products in animal feeds.

Using a modified mechanical development system from composite flour, the simple bakery built adjacent to the mill now operates at full capacity producing 700 loaves a day containing up to 20% of sorghum flour in a composite with wheat. The Federal and Northeast State Governments in Nigeria, in cooperation with IDRC, are now working out plans for the establishment of a series of similar milling and processing units to be located across the northern semi-arid regions of the country.

It is believed the Maiduguri mill development took into account a most important consideration often overlooked in food technological development; namely the importance of satisfying the consumer. It is a basic philosophy not widely shared that all food and agricultural research and development programs revolve around two mutually dependent and equally important human foci: (1) the farmer producer; and (2) the consumer: the two being linked through the post-production system in which food science and technology is of dominant importance. Consequently, as stated earlier, every production system and its dependent post-production system must begin with a comprehensive understanding of the socioeconomic conditions, needs, attitudes and constraints of both the farmer and the consumer in relation to one another, and in relation to the environments in which they exist. Without a thorough and sympathetic understanding of the attitudes, opportunities, and constraints which condition the lives and needs of the producer and the consumer, almost all post-production research and technology will be of little avail.

It is certain that a great many serious constraints to improved agricultural production and post-production systems could be eliminated if these were brought to the attention of a broader spectrum of scientific competence. It is sad but true

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that many decisions made by the administrators of multilateral and bilateral development agencies are guided more by political expedience than by scientific logic. There is therefore an urgent and pressing need for the world scientific community in both developed and developing countries to gain not only a more comprehensive understanding but also a greater degree of influence over those whose decisions determine food and agricultural research and development policies. This is not to denigrate or devalue the important role of many existing multilateral and bilateral development agencies, but it must be recognized that most are guided by some measure of self interest or political pressure. The international scientific unions and their member organizations cut across all sorts and conditions of scientific men, women, academic institutions, international agencies, national governments, private, public and parastatal corporations. They therefore represent a formidable and as yet virtually untapped source of scientific wisdom and technological experience.

In the minds of many of our contemporaries, science appears to be equated more with the evils of destruction and despoliation than with the virtues of creating a more just society and the satisfaction of human needs. Is it not time for scientists of the world to unite in order to demonstrate that they wield and can exert almost limitless power for human benefit? And should we not begin with an internationally organized scientific assault upon the most basic and universal of all human needs - the need for an adequate diet. In achieving this end, food scientists and technologists have an extremely important role to play.